Clinical Outcomes of Segmental Sandwich Osteotomy to Gain Vertical Bone Height in the Anterior Maxilla Before Implant Placement

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List of Abbreviations

GBR	Guided bone regeneration
et al.	et alii (Latin) in English and others
mm	Milimeter
Ncm	Newton centimeter
CBCT	Cone Beam Computed Tomography
vs.	versus (Latin) in English compared to
A	Autogenous bone
Ti	Titanium
KMM	Kaung Myint Myat
AB	Amira Begic
NK	Nadine Krockow
n	number
ND	No Data
TG	Test group
CG	Control group

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Declaration by candidate

I hereby declare under oath that all information in this master's thesis has been obtained and presented in accordance with academic rules and ethical conduct. This master's thesis is the product of my own independent work.

I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

This thesis has neither been submitted to another committee, nor has it been published before.

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Date, Signature

Abstract

Introduction

The vertical bone height in the anterior maxilla is crucial for successful dental implant placement and restoration of oral function and aesthetics. Insufficient bone height poses a significant challenge in implant dentistry, necessitating vertical bone augmentation procedures. Among these procedures, segmental sandwich osteotomy has gained attention as a potential solution.

Material and Methods

A systematic review of the literature was conducted to identify relevant studies on the topic. Randomized clinical trials reporting on the use of segmental sandwich osteotomy in the anterior maxilla were included. Data regarding patient demographics, surgical technique, complications, and implant success rates were extracted and analysed.

Results

Two of the studies included in the meta-analysis reported a mean vertical bone gain of 4.05±0.7 mm at the final follow-up. Another study reported a mean vertical bone gain of 3.34 mm with autogenous inlay bone graft compared to -0.02 mm with autogenous onlay bone graft at the final follow-up. The meta-analysis showed an overall standardized mean difference (SMD) of 0.40, with a 95% confidence interval of [-0.35, 1.15] in the fixed-effect model and [-1.00, 1.79] in the random-effect model. The p-value was 0.77, indicating no statistical significance, with minimal heterogeneity ($Tau^2 = 0$, $I^2 = 0.0\%$).

Conclusion

Segmental sandwich osteotomy offers a viable option for vertical bone augmentation in the anterior maxilla, with favourable clinical outcomes and low complication rates. Its ability to utilize existing bone without the need for external grafts makes it an attractive option for patients requiring vertical bone augmentation. However, further research is needed to confirm these findings and address remaining concerns regarding the predictability and long-term stability of the technique.

Introduction

Dental implants are considered a standard treatment option for restoring oral function in both fully and partially edentulous patients. In the maxillary anterior esthetic zone, the available vertical bone height plays a pivotal role in the success of dental implant rehabilitation. A deficiency in the height of the alveolar ridge poses a significant challenge, potentially complicating the implant placement process. Previous studies have consistently shown that when the anterior alveolar bone height is less than 10mm, vertical ridge augmentation is often necessary either before or concurrently with implant placement to ensure optimal outcomes (1–3).

Various bone augmentation procedures have been developed to address the challenge of insufficient vertical bone height in the maxillary esthetic zone. These procedures include guided bone regeneration (GBR), onlay bone grafting, the tent pole technique, vertical reconstruction using titanium mesh with autogenous bone graft, and distraction osteogenesis (4). While these techniques have demonstrated high success rates in vertical bone augmentation, they are not without drawbacks. Concerns such as donor site morbidity, the need for second-stage surgery, increased treatment duration, and elevated costs are commonly associated with these procedures (5–7).

Despite their limitations, addressing vertical bone deficiency remains a critical aspect of implant dentistry. Ongoing research endeavours aim to improve the efficacy and minimize the drawbacks of existing augmentation techniques. Future developments may focus on refining surgical protocols, integrating advanced technologies, and exploring novel biomaterials to enhance the predictability and long-term success of vertical bone augmentation procedures in the anterior maxilla. By addressing these challenges, clinicians can continue to advance the field and provide patients with more effective and sustainable treatment options for implant rehabilitation (8).

The segmental sandwich osteotomy (inlay bone graft) with the use of inter-positional bone graft was first advocated by Schettler in the anterior mandible in 1974 (9). With the development of implant dentistry, this technique has been used with high success rates for vertical alveolar bone augmentation at the deficient anterior maxilla with adequate width. This involves placing one horizontal and two vertical full-thickness osteotomies via a buccal approach to down-fracture a bony segment vertically in the coronal direction while preserving the integrity and blood supply from the palatal mucosa. Moreover, it can be utilized with various bone graft materials without donor

site morbidity and allows for simultaneous implant placement, thereby reducing the overall treatment time to final restoration.

Furthermore, the segmental sandwich osteotomy offers benefits such as fewer incidences of wound dehiscence and graft exposure, less disturbance to the crestal periosteum, and the creation of a highly vascularized graft bed, which enhances graft incorporation with the recipient site. Despite these advantages, there is a debate regarding the predictability of this technique due to the potential palatal tipping of the mobilized down-fracture segment, which may negatively impact the amount of vertical bone augmentation achieved. Further research and refinement of the surgical approach may be necessary to address these concerns and optimize the outcomes of segmental sandwich osteotomy in vertical bone augmentation procedures (10).

Purpose

The purpose of the study is to evaluate the clinical outcomes of segmental sandwich osteotomy as a method for gaining vertical bone height in the anterior maxilla prior to implant placement. This involves assessing the effectiveness and predictability of the technique in achieving adequate vertical bone augmentation while minimizing complications. Key aspects of interest include the success rate of the procedure, the incidence of complications such as wound dehiscence and graft exposure, as well as the long-term stability of the augmented bone.

Aim

The aim of the present systematic review is to document the level of evidence on the efficacy of the segmental sandwich osteotomy to provide increased vertical bone height of the alveolar process for later implant placement in the anterior maxilla.

Background to Thesis and Review of the literature

Dental Implant Placement in the Atrophic Anterior Maxilla

Dental implants have become a cornerstone in restorative dentistry, providing a reliable and durable solution for replacing missing teeth and restoring oral function. Unlike traditional prosthetic devices such as bridges or dentures, implants offer a more stable and aesthetically pleasing option, which integrates seamlessly with the patient's natural dentition. This integration significantly improves both the functionality and

appearance of the teeth, contributing to better overall oral health and patient satisfaction.

The success of dental implant placement is highly dependent on the availability of adequate bone volume and density at the implant site. Adequate bone support is essential to ensure the stability and longevity of the implants. In the anterior maxilla, where aesthetics plays a critical role, vertical bone height is particularly crucial. This area of the mouth is prominently visible when speaking or smiling, making it essential to achieve optimal outcomes in terms of both function and appearance.

Insufficient bone height in the anterior maxilla can pose significant challenges during implant placement. It can lead to difficulties in achieving the necessary stability and may compromise the final aesthetic result. Patients with vertical bone deficiencies may face increased risks of implant failure or may require additional surgical procedures to augment the bone before implants can be successfully placed. These additional procedures can increase the complexity, cost, and duration of treatment, making it more challenging for both patients and clinicians.

Given these challenges, the development and refinement of techniques for vertical bone augmentation in the anterior maxilla are of paramount importance. Effective augmentation techniques can enhance the predictability and success of dental implants, ensuring that patients receive the best possible outcomes in terms of both function and aesthetics.

Aetiology of Vertical Bone Deficiency in the Anterior Maxilla

Vertical bone deficiency in the anterior maxilla can occur due to several factors, each contributing to the loss of bone height and volume essential for successful dental implant placement.

Tooth loss is a primary cause of vertical bone deficiency. When a tooth is lost, the alveolar ridge, which supports the tooth, begins to resorb over time due to the lack of stimulation that normally occurs during chewing. This resorption can lead to significant reductions in bone height and volume, making it difficult to place dental implants without additional augmentation procedures.

Trauma to the oral region can cause significant damage to the bone structure, leading to vertical bone deficiency. Accidents, falls, or sports injuries can fracture the alveolar bone or cause severe damage that results in bone loss. The extent of bone damage from trauma can vary, but it often necessitates surgical intervention to rebuild the bone structure to support implants.

Periodontal disease, a chronic infection of the gums and supporting structures of the teeth, is another major factor contributing to bone loss. In advanced stages, periodontal disease leads to the destruction of the alveolar bone, resulting in decreased bone height and density. This bone loss not only affects the stability of natural teeth but also compromises the potential for successful implant placement.

Alveolar ridge resorption is a natural process that occurs following tooth extraction. Without the natural mechanical stimulation provided by a tooth, the bone tissue in the alveolar ridge gradually diminishes. This process can be accelerated by factors such as age, systemic health conditions, and the length of time the tooth has been missing. When the available bone height in the anterior maxilla is insufficient to accommodate dental implants, vertical ridge augmentation becomes necessary. This augmentation involves various surgical techniques to increase bone height and create a stable environment for implant placement. Effective vertical ridge augmentation is crucial for ensuring the success of implants, particularly in the anterior maxilla, where aesthetic outcomes are highly significant. By addressing these causes of bone deficiency through augmentation, clinicians can improve the chances of successful implant integration and patient satisfaction.

Augmentation Techniques for Dental Implant Placement

Several techniques have been developed to address vertical bone deficiency in the anterior maxilla, each with its own set of advantages and limitations.

Guided Bone Regeneration (GBR) involves the use of barrier membranes to direct the growth of new bone at the site of deficiency. The barrier membrane acts to isolate the bone defect from surrounding soft tissues, allowing bone cells to populate the area and regenerate the deficient bone. This technique is highly effective in promoting bone growth, but it requires precise surgical technique and careful postoperative management to avoid complications such as membrane exposure or infection (11).

Onlay Bone Grafting involves placing a bone graft directly onto the existing bone surface. The graft material, which can be autogenous (harvested from the patient's own body), allografts (donor bone), or synthetic, integrates with the existing bone to increase its height and volume. This method is advantageous in providing a significant increase in bone mass, but it often requires a secondary surgical site for graft harvesting, leading to increased morbidity and prolonged recovery times (12).

The Tent Pole Technique uses tenting screws or poles to create space and support the overlying soft tissue while bone graft material is placed underneath. This technique

helps maintain the shape and volume of the augmented area, preventing the collapse of the graft material during the healing process. Although effective, the technique can be complex and requires precise placement of the screws to avoid complications such as screw loosening or infection (4).

Vertical reconstruction using titanium mesh involves the combination of a rigid mesh framework and autogenous bone graft. The titanium mesh provides structural support and shape, while the bone graft fills the defect, promoting new bone formation. This method is particularly useful for large defects and provides excellent stability. However, it can be associated with higher costs, prolonged treatment times, and potential complications such as mesh exposure or infection (13).

Distraction Osteogenesis is a technique that gradually stretches the bone to promote new bone growth. The process involves making a surgical cut in the bone and slowly separating the two segments using a specialized device. As the bone segments are pulled apart, new bone forms in the gap. This method can achieve significant bone height increases but requires a lengthy treatment period and meticulous patient compliance to ensure successful outcomes (14).

While each of these augmentation techniques offers distinct benefits, they also come with inherent limitations and potential complications. Common challenges include donor site morbidity, the need for a secondary surgical procedure, prolonged treatment times, and increased costs. Additionally, complications such as graft resorption, wound dehiscence, and implant failure may occur, particularly in complex cases or patients with compromised health. Therefore, selecting the most appropriate technique requires careful consideration of the patient's specific needs, the extent of bone deficiency, and the potential risks and benefits of each method.

Segmental Sandwich Osteotomy in the Atrophic Anterior Maxilla

Segmental sandwich osteotomy, also known as inlay bone grafting, has emerged as a promising alternative for vertical bone augmentation in the anterior maxilla. This technique involves creating horizontal and vertical osteotomies to down-fracture a bony segment while preserving the integrity and blood supply from the palatal mucosa. With advancements in implant dentistry, segmental sandwich osteotomy has been adapted for vertical alveolar bone augmentation in the anterior maxilla (2).

Segmental Sandwich Osteotomy Step-by-Step Procedure

The segmental sandwich osteotomy involves several key steps. It begins with preoperative planning, which includes a detailed radiographic analysis to assess bone

volume and structure. This is followed by the administration of local or general anaesthesia and making a buccal incision. Horizontal and vertical osteotomies are then made to create a movable bone segment, which is carefully down-fractured to create space for the graft. The created space is filled with bone graft material, which may include autogenous bone, allografts, or synthetic materials. The bone segment is then stabilized using fixation devices such as screws or plates. Finally, the surgical site is closed, ensuring minimal disruption to the blood supply.

Advantages of Segmental Sandwich Osteotomy

By utilizing a buccal approach and careful manipulation of bone segments, it offers several advantages over other augmentation methods. It reduces donor site morbidity by minimizing the need for external bone grafts and associated complications. The technique allows for a shorter treatment time by enabling simultaneous implant placement with bone grafting. Additionally, it utilizes the patient's existing bone, which decreases the risk of graft rejection or resorption. The preserved blood supply from the palatal mucosa promotes faster healing and graft incorporation, further enhancing the overall effectiveness of the procedure (3,15).

Controversies and Challenges

Despite its potential benefits, segmental sandwich osteotomy is not without controversy. One of the main concerns is the risk of palatal tipping of the mobilized bone segment, which may compromise the predictability and stability of vertical bone augmentation. Additionally, proper case selection, surgical technique, and postoperative management are critical factors that influence the success of the procedure. Palatal tipping can lead to uneven bone augmentation, and not all patients are ideal candidates for this procedure. The surgical technique requires a high level of precision and expertise, while postoperative management is essential for minimizing complications and ensuring successful outcomes.

Several studies have investigated the clinical outcomes of segmental sandwich osteotomy for vertical bone augmentation in the anterior maxilla. These studies have reported favourable results in terms of implant success rates, bone graft integration, and aesthetic outcomes. However, there is still a need for further research to validate these findings and address remaining concerns regarding the predictability and long-term stability of the technique (3,15–18).

Hypothesis

It is hypothesized that the clinical outcomes of segmental sandwich osteotomy are effective compared to other techniques for vertical bone augmentation.

Research Question

Is segmental sandwich osteotomy an effective treatment to gain vertical bone height in the anterior maxilla before implant placement?

Material and Methods

Objective of the Study

The present systematic review followed the PRISMA-P 2015 statement for reporting systematic reviews (Preferred Reporting Items for Systematic reviews and Meta-Analyses-Protocols).

Study Question/PICO Strategy

The following detailed and structured question was developed according to the population, intervention, comparison and outcome (PICO):

- Population (P): Patients with partially edentulous vertically atrophic anterior maxilla
- Interventions (I): Sandwich osteotomy technique to augment atrophic anterior maxilla to allow later implant placement and prosthetic rehabilitation (fixed)
- Comparison (C): Nil
- Outcomes (O):
- Primary: vertical bone gain

secondary: surgical complications, implant survival rate, prostheses survival rate, peri-implant marginal bone loss

Eligibility Criteria

Inclusion criteria

- Studies including reporting data on at least 10 patients treated with implant-supported dental prostheses after vertical ridge augmentation by means of the sandwich osteotomy technique
- Follow-up time at least 12 months after loading
- All study types
- Human studies

Exclusion criteria

- Case reports
- Case series
- Experimental studies
- Animal studies

Types of Outcome Measures

Vertical bone gain was the primary outcome. The following parameters were secondary outcome measures: author, year of publication, study design, groups, operator, study setting, funding, follow-up after implant loading, number of patients, gender, mean age, smoking habits, graft location, inclusion and exclusion criteria, graft material, fragments stabilization, use of membrane, healing time, additional procedure, implant characteristics, loading protocol, type of prosthesis, dropouts, implant and prosthesis survival rates, complications, peri-implant bone resorption.

The primary outcome was vertical bone gain and secondary outcomes were surgical complications, implant survival rate, prostheses survival rate, peri-implant marginal bone loss.

Search Strategy

The search strategy involved searching the electronic databases of MEDLINE (PubMed), EMBASE, COCHRANE LIBRARY, SCOPUS in October, 2023.

The following key words were inserted in various combinations according to the instructions of each search engine: sandwich AND osteotomy OR segmental AND osteotomy OR segmental AND sandwich AND osteotomy AND dental AND implant. Only papers published in English were taken into consideration. No restrictions regarding gender, age or publication date were applied.

Study Selection and Data Selection Process

Retrieved data were screened independently by two of the authors (KMM, AB) using dedicated extraction table sheets prepared during the developing phase of the protocol. Any disagreement was solved through discussion consulting a senior experienced reviewer (NK).

Titles and abstracts identified through the search phase, which did not meet the inclusion criteria or did not provide significant information regarding the investigated technique, were excluded.

Data extraction from full-text articles meeting the inclusion criteria was performed by two of the authors (KMM, AB). All retrieved data were then discussed among all authors to reach consensus.

Data Extraction Process

All data were extracted independently by two of the reviewers (KMM, AB) using data extraction sheets. Any potential disagreement was discussed and solved by consulting a third party (NK).

The following parameters were extracted: author, year of publication, study design, groups, operator, study setting, funding, follow-up after implant loading, number of patients, gender, mean age, smoking habits, graft location, inclusion and exclusion criteria, graft material, fragments stabilization, use of membrane, bone height achieved after reconstructive procedure, bone gain at follow-up, healing time, additional procedure, implant characteristics, loading protocol, type of prosthesis, dropouts, implant and prosthesis survival rates, complications, peri-implant bone resorption.

The primary outcome was vertical bone gain and secondary outcomes were surgical complications, implant survival rate, prostheses survival rate, peri-implant marginal bone loss.

Quality and Risk of Bias Assessment in individual Studies

Two of the authors (KMM, AB) independently evaluated the methodological quality of all included studies using a dedicated quality assessment form (Cochrane Collaboration's tool for assessing risk of bias adapted from Higgins and Altman) Fig.2 Moreover, any disagreement was solved through discussion with a third party (NK).

Data Analysis/Statistical Methods

In the process of synthesizing results, the effect measures for continuous outcomes were presented by standardized mean differences between two distinct groups, namely the test and control groups. Subsequently, the synthesized results underwent re-expression through meta-analysis of mean differences. This meta-analysis, integrating quantitative findings from separate yet similar studies, aimed to provide a numerical estimate of the overall effect of interest.

Initially, the fixed-effects model was employed, assuming that all studies originate from a general population, with no significant differences in sizes among different trials. This assumption underwent verification through the heterogeneity test, specifically Cochran's Q test. However, considering the sufficient commonality among the included studies to justify data analysis, the random-effects model was deemed more appropriate. It's worth noting that no rationale exists to posit that studies are identical

in terms of the true effect size across all studies. This model was preferable as it accommodates both random variation within studies and variation among different studies. Consequently, individual trials were pooled, and the weighted mean difference for the outcome was computed.

Statistical heterogeneity was further assessed utilizing the Cochran Q test and Higgins I^2 statistic. To ascertain statistical significance, a significance level of p-value < 0.05 was chosen. Moreover, to visually represent differences among the results of the evaluated outcome, both a forest plot and a funnel plot were generated.

Results

Study Selection

The systematic screening and selection process are outlined in figure 1. During the identification process, 381 records were obtained. Among these, 375 studies were considered after duplicates removal. After screening of the titles, 375 abstracts analysed. Following the full text analysis of 20 articles, 5 studies fulfilled the inclusion criteria and were included.

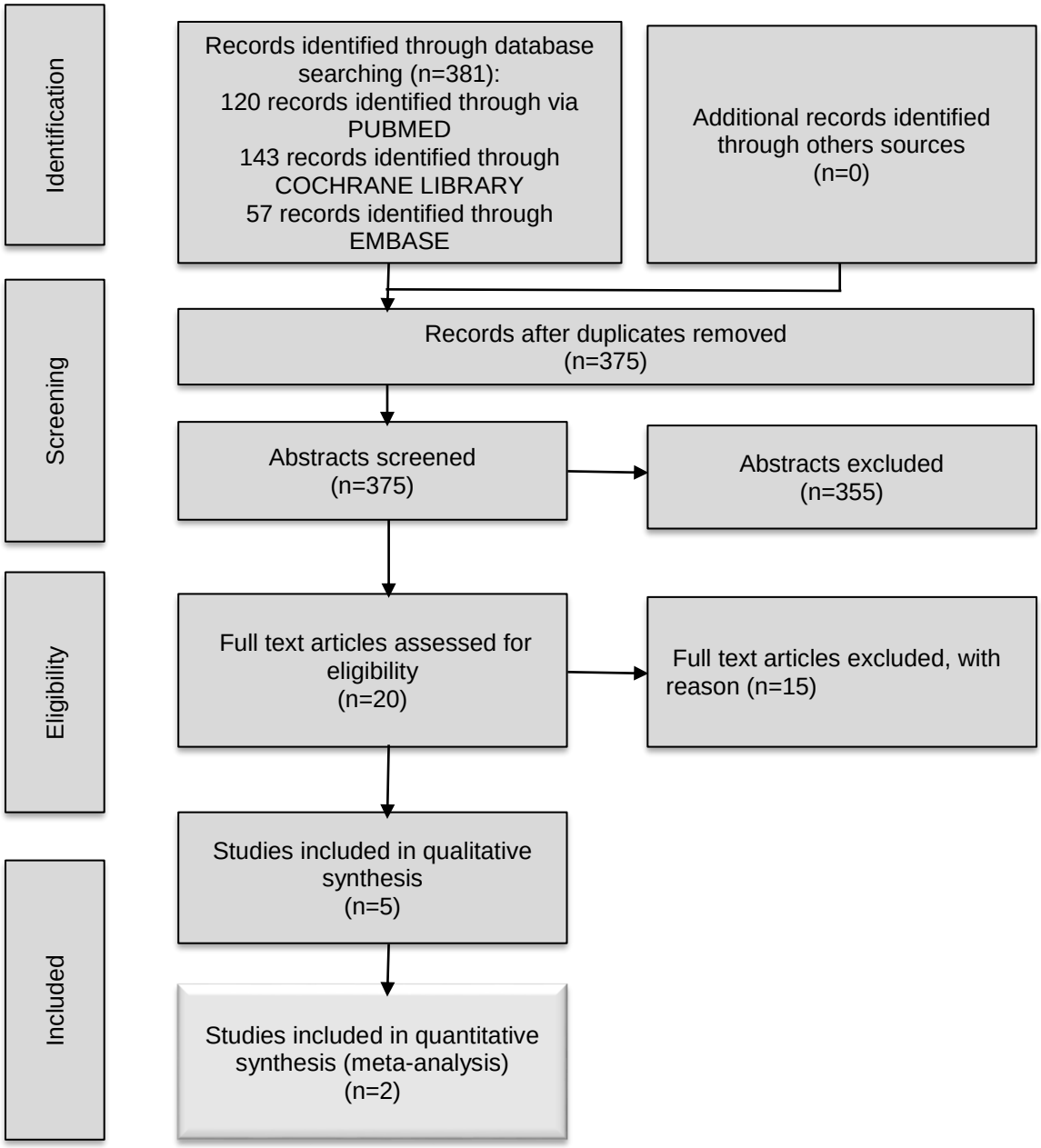


Figure 1 Flowchart of the systematic review.

Table 1 List of the excluded studies following full-text analysis

	Reason for exclusion		
	Sandwich osteotomy in posterior mandible	Retrospective study	Less than 10 patients treated
Publications	Roccuzzo et al. 2020 (19) Kamperos et al. 2017 (20) Starch-Jensen et al. 2020 (21) Starch-Jensen et al. 2018 (22) Noia et al. 2016 (23) Rachmiel et al. 2018 (24) Marconcini et al. 2018 (25) Geng et al. 2019 (26) Terheyden at al. 2021 (27) Felice et al. 2009 (28) Bormann et al. 2010 (29)	Chan et al. 2021 (30) Jensen et al. 2006 (2)	Mansour et al. 2018 (1) Bell et al. 2013 (31)

Study Range and Characteristics

All the included studies were RCTs which compared at least two groups. All the studies reported data on patients treated at the Department of Oral and Maxillofacial Surgery, Cairo University, Egypt. The number of surgeons involved was clearly defined in most of the studies.

Sample and patient characteristics

Combining data from the 5 included studies, 76 patients (mean age 39 years) were treated by means of the sandwich osteotomy technique and eventually received implants in the augmented sites (n=60). Detailed inclusion and exclusion criteria were provided in all studies.

Augmentation procedure

All included articles clearly described the augmentation procedure. Inter-positional grafting materials included: autogenous bone blocks harvested from the chin, particulate and block xenograft, alloplastic bone block. Stabilization of the transport segments by using miniplates and mini screws in three articles and simultaneous implant placement in two articles. None of articles reported the use of a resorbable membrane to cover the grafted area. Healing time from the bone augmentation procedure to implant placement ranged from four to six months.

Implant and prosthetic characteristics

The 76 patients (all 5 studies) received a total of 115 implants (only 4 studies) after sandwich osteotomy. Only two studies presented data on implant brand except length and diameter, the other two studies presented data on mean length except diameter and brand while the remaining one study presented no data on implant length, diameter and brand. All implants in the included studies underwent a delayed loading protocol with 4 or 6 months of healing after implant placement. There was no reporting data on implant prosthetic characteristic in all studies.

Table 2 Characteristics of the included studies

Author	Year of Publication	Title of Study	Follow Up (months)	Number of Patients		
				Total	TG	CG
Al-Dubai et al.	2022	RCT	4	16	8	8
Nazzal et al.	2021	RCT	4	12	6	6
El Zahwy et al.	2019	RCT	6	16	8	8
El Hadidy et al.	2018	RCT	4	16	8	8
Mounir et al.	2017	RCT	6	16	8	8

Author	Age				Gender	
	Age (range)	Age (mean)	TG Age (mean)	CG Age (mean)	No. Females	No. Male
Al-Dubai et al.	ND	39.25	38.5±11.24	40±7.89	11	5
Nazzal et al.	ND	38.35	41.7±12.8	35±7.1	7	5
El Zahwy et al.	ND	38.5	39	38	6	10
El Hadidy et al.	25-55	40	ND	ND	5	11
Mounir et al.	25-53	39	ND	ND	6	10

Author	Number of Implants		
	Total	TG	CG
Al-Dubai et al.	35	17	18
Nazzal et al.	ND	ND	ND
El Zahwy et al.	40	20	20
El Hadidy et al.	40	20	20

Mounir et al.	40	20	20	
Author	Procedure		Fragment Stabilization	Type of Graft
	TG	CG		
Al-Dubai et al.	Sandwich osteotomy with simultaneous implant placement	Sandwich osteotomy with delayed implant placement	Miniplates & mini-screws	Xenograft
Nazzal et al.	Sandwich osteotomy with simultaneous implant placement using PSGs	Sandwich osteotomy with conventional technique	ND	Xenograft
El Zahwy et al.	Autogenous inlay bone graft	Autogenous onlay bone graft	ND	Autogenous block
El Hadidy et al.	Palatal approach for sandwich osteotomy	Buccal approach for sandwich osteotomy	Miniplates & mini-screws	Alloplastic block
Mounir et al.	inlay bone graft	Onlay bone graft with titanium mesh	Ti mesh & mini-screws, miniplates & mini-screws	Particulate & block xenograft

Data Extraction: qualitative Synthesis

The findings presented demonstrate a consistent and commendable methodological rigor across the studies surveyed, spanning from 2017 to 2022. Each study rigorously adhered to fundamental research principles, including randomization and allocation concealment, thereby bolstering the reliability of their respective conclusions. Moreover, all investigations maintained the integrity of their outcomes through assessor blindness, minimizing potential biases. Notably, the absence of significant patient dropouts in any of the studies underscores robust participant engagement and strengthens the validity of the results obtained. Collectively, these outcomes affirm the

high quality and trustworthiness of the methodologies utilized, lending considerable credibility to the overall body of research in this domain.

Table 3 Quality Assessment of the included studies

Author, year of publication and type of study	**Randomization**	**Allocation concealment**	**Outcome assessor blindness**	**Patient's dropout**	**Risks of bias**
Al-Dubai et al, 2022, RCT	YES	YES	YES	NO	LOW
Nazzal et al, 2021, RCT	YES	YES	YES	NO	LOW
El Zahwy et al, 2019, RCT	YES	YES	YES	NO	LOW
El Hadidy et al, 2018, RCT	YES	YES	YES	NO	LOW
Mounir et al, 2017, RCT	YES	YES	YES	NO	LOW

Data Extraction: quantitative Synthesis

Al-Dubai et al. reported that the mean vertical bone gain in the study group averaged 4.04 ± 0.59 mm, while in the control group, it measured 3.86 ± 0.52 mm. However, statistical analysis revealed no significant difference between the two groups ($p = 0.518$). Similarly, the mean bone gain percentage was 33.02% in the study group and 31.75% in the control group. Again, there was no statistically significant difference observed ($p = 0.656$).

Nazzal et al. described uneventful procedures overall, with only one case in the study group showing a cracked bony segment, which did not impact the final outcome. Radiographic assessments indicated similar levels of bone gain in both study and control groups, with no statistically significant difference noted (4.4 mm in the study group versus 3.9 mm in the control group). However, the introduction of a computer-guided approach yielded notable benefits, notably reducing palatal tipping to 0.4 mm compared to 2.1 mm in the conventional group. This reduction was statistically

significant ($p < 0.001$), indicating the superiority of the computer-guided technique in minimizing palatal tipping during the procedure.

El Zahwy et al. reported uneventful wound healing in the majority of cases, although three cases in the onlay group experienced wound breakdown and graft loss. In terms of vertical bone gain, the control group exhibited a mean of -0.02 mm, while the study group showed an average gain of 3.34 mm. Furthermore, crestal bone loss measurements revealed a mean loss of 4.77 mm in the control group compared to 1.65 mm in the study group. These findings suggest that the intervention employed in the study group led to significant improvements in both vertical bone gain and preservation of crestal bone compared to the control group.

El Hadidy et al. reported that all cases demonstrated uneventful wound healing, and a total of 40 delayed implant placements were performed. Their results indicated no statistically significant differences between the two groups concerning bone height ($P = .43$) and labial prominence ($P = .5$). This suggests that the intervention did not significantly influence these parameters compared to the control group.

Mounir et al. reported no statistically significant difference between the two groups ($P = 0.2$). The mean percentage of vertical bone gain six months postoperative was 20.7% in the control group and 31.6% in the study group.

Primary outcome - Vertical bone gain

Only 2 studies provided data on initial alveolar bone height, 4 months postoperative bone height and vertical bone gain at the final follow-up. The mean height of the alveolar process before augmentation was 11.46±0.7 mm (median mm, range 10.76-12.16mm), 4 months postoperative bone height was 15.51±0.86 mm (median mm, range 14.65-16.37 mm) and the mean vertical bone gain at the final follow-up was 4.05±0.7 mm (median mm, range 3.35-4.75 mm).

Surgical complications

Intraoperative and postoperative complications were not reported consistently. As intraoperative complications, one cracked bony segment was detected in one patient (15). One cracked bony segment was also detected in one patient (3). As postoperative complications, 5 flap dehiscence and graft exposures were reported in five patients (16). One flap dehiscence and titanium mesh exposure was reported in one patient (18).

Table 4 Clinical Outcome

	Preoperative Vertical Bone Gain				Immediate Postoperative Bone Height			
Author	TG	TG SD	CG	CG SD	TG	TG SD	CG	CG SD
Al-Dubai et al.	12.31	0.73	12.24	0.89	16.73	0.8	16.56	0.94
Nazzal et al.	10.6	0.48	10.7	0.72				
El Zahwy et al.	11.11	2.14	11.92	3.1	16.1	1.93	16.67	2.69
El Hadidy et al.	8.82	3.21	9.96	2.38	20.41	3.28	15.57	2.28
Mounir et al.	ND	ND	ND	ND	ND	ND	ND	ND

	4 months Postoperative Bone Height				6 months Postoperative Bone Height			
Author	TG	TG SD	CG	CG SD	TG	TG SD	CG	CG SD
Al-Dubai et al.	16.35	0.81	16.1	0.86				
Nazzal et al.	15	1.23	14.6	0.55				
El Zahwy et al.					14.45	1.66	11.9	1.87
El Hadidy et al.	19.32	3.32	14.66	2.31	ND	ND	ND	ND
Mounir et al.	ND	ND	ND	ND	ND	ND	ND	ND

	Bone Gain	Complications

Author	TG Bone Gain (mm)	CG Bone Gain (mm)	TG Bone gain (%)	CG Bone gain (%)	
Al-Dubai et al.	4.04±0.59	3.86±0.52	33.02±5.64	31.75±5.49	1
Nazzal et al.	4.4±1.05	3.9±0.65	41.8±10.1	36.9±8.2	1
El Zahwy et al.	3.34	-0.02	ND	ND	5
El Hadidy et al.	ND	ND	76.59±11.72	79.9%±8.69	0
Mounir et al.	ND	ND	31.6±22.5	20.7±13.3	1

ND= no data

Meta-Analysis

The provided data presents a meta-analysis employing both fixed and random effects models to evaluate the standardized mean difference (SMD) across two subgroups, each comprised of one study.

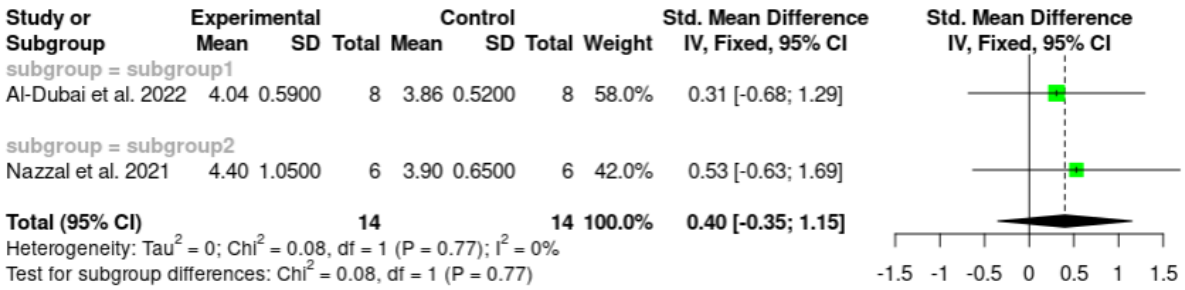


Figure 2 Forrest Plot (fixed effect)

The forest plot in Figure 2 presents the standardized mean differences (SMD) for the two included studies, Al-Dubai et al. 2022 and Nazzal et al. 2021, using a fixed effects model. Al-Dubai et al. 2022 reported an SMD of 0.31 with a 95% confidence interval of [-0.68, 1.29], indicating no statistically significant difference between the study and control groups. Similarly, Nazzal et al. 2021 reported an SMD of 0.53 with a 95% confidence interval of [-0.63, 1.69], also indicating no significant difference. The overall

SMD combining these studies is 0.40 with a 95% confidence interval of [-0.35, 1.15], and a non-significant p-value of 0.77. This suggests that, under the fixed effects model, there is no significant improvement in vertical bone gain with the sandwich osteotomy technique compared to the control.

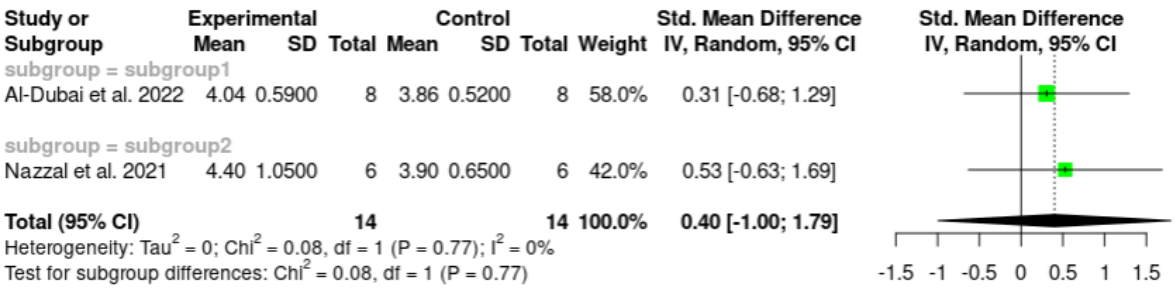


Figure 3 Forrest Plot (random effect)

The forest plot in Figure 3 shows the SMDs for the same studies using a random effects model. In this model, Al-Dubai et al. 2022 has an SMD of 0.31 and Nazzal et al. 2021 has an SMD of 0.53. The combined SMD under the random effects model is also 0.40, but with a wider 95% confidence interval of [-1.00, 1.79], reflecting greater uncertainty. The non-significant p-value of 0.77 remains unchanged. The random effects model accounts for potential variability between studies, but the lack of statistical significance suggests that any observed differences in vertical bone gain between the sandwich osteotomy technique and the control are likely due to chance rather than a true effect.

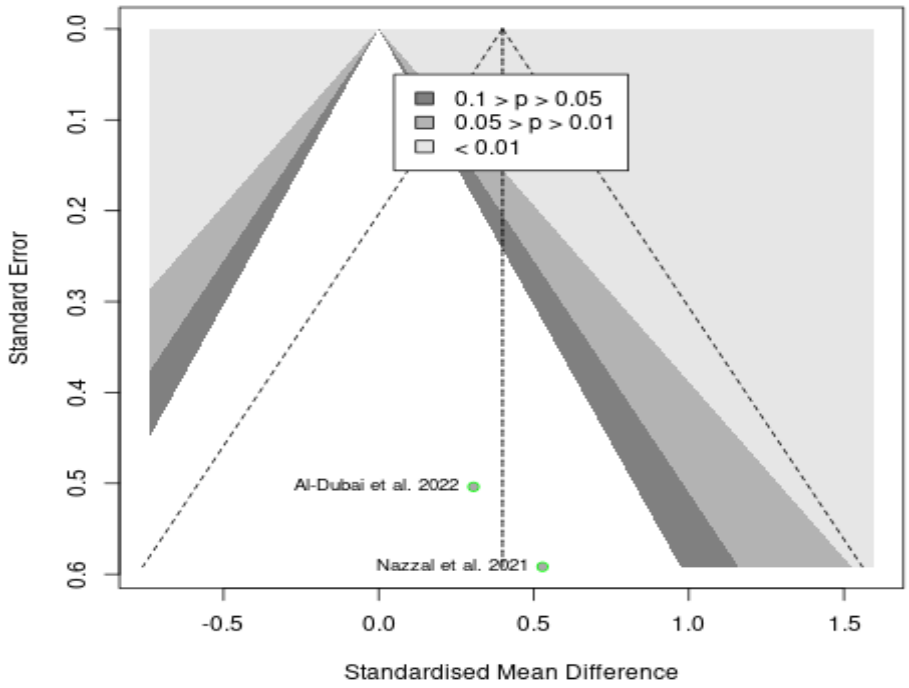


Figure 4 Funnel Plot

Figure 4 presents a funnel plot used to assess the presence of publication bias in the included studies. The plot shows data points for Al-Dubai et al. 2022 and Nazzal et al. 2021, both falling within the expected range of the plot, indicating no significant asymmetry. This suggests that there is no substantial publication bias in the meta-analysis. The symmetry of the funnel plot implies that the studies included in the analysis are representative of the broader research and that the results are not unduly influenced by selective reporting or publication of only positive findings.

Discussion and Conclusion

Discussion

The objective of this systematic review and meta-analysis was to evaluate the evidence supporting the use of segmental sandwich osteotomy to enhance vertical bone height in the anterior maxilla for subsequent implant placement. Five studies with a low risk of bias met the inclusion criteria and were included in the review. Two of these studies reported a mean vertical bone gain of 4.05±0.7 mm at the final follow-up. Another study reported a mean vertical bone gain of 3.34 mm with autogenous inlay bone graft compared to -0.02 mm with autogenous onlay bone graft at the final follow-up. (3,15,16).

One study documented a mean vertical bone gain at the final follow-up with a palatal approach sandwich osteotomy of 76.59±11.72% compared to 79.9±8.69% with a buccal approach (17). Another study reported a mean vertical bone height gain with inlay bone graft of 31.6±22.5% compared to 20.7±13.3% with onlay bone graft and titanium mesh (18). According to these studies, sandwich osteotomy with simultaneous implant placement achieved greater vertical bone height than the conventional two-stage surgery. Additionally, the sandwich osteotomy technique provided more vertical bone height compared to other techniques such as autogenous onlay bone graft and onlay bone graft with titanium mesh.

The meta-analysis showed that the overall standardized mean difference (SMD) combining these studies is 0.40, with a 95% confidence interval of [-0.35, 1.15] in the fixed-effect model and [-1.00, 1.79] in the random-effect model, and a p-value of 0.77, which was not statistically significant, with minimal heterogeneity ($Tau^2 = 0$, $I^2 = 0.0\%$). The use of various grafting materials, including autogenous, bovine, and hydroxyapatite, to stabilize vertically moved transport segments in mandibular corrective surgery highlights the diverse options available for enhancing bone healing and stability. The lack of clear superiority among these materials suggests that each may offer advantages depending on clinical scenarios or patient populations, such as availability, biocompatibility, and resorption rates. Furthermore, the use of miniplates, mini-screws, and simultaneous implant placement without barrier membranes in stabilizing transport segments emphasizes the importance of biomechanical stability and the potential for osseointegration to support long-term outcomes. However, further

comparative studies are needed to determine the optimal material choices and surgical techniques based on specific patient characteristics and treatment goals.

Regarding surgical complications, the sandwich osteotomy technique resulted in only 2 cases of cracked bony segments in two patients across all studies, whereas the autogenous onlay bone graft technique had 5 cases of flap dehiscence and graft exposure in five patients. The onlay bone graft with titanium mesh technique reported 1 case of flap dehiscence and titanium mesh exposure in one patient. The lower incidence of complications associated with the sandwich osteotomy technique compared to autogenous onlay bone grafting or onlay bone grafting with titanium mesh can be attributed to several factors. Firstly, the sandwich osteotomy technique involves precise segmentation of the jaws, allowing for controlled repositioning of bone segments, which minimizes the risk of segmental instability or fracture. Additionally, placing bone grafts between segments provides structural support and promotes more efficient bone healing, reducing the likelihood of complications such as flap dehiscence or graft exposure. Furthermore, the use of bone grafts in sandwich osteotomy may create a better biological environment for bone regeneration, leading to enhanced tissue integration and a decreased risk of complications. Overall, the meticulous surgical approach and supportive biological environment provided by the sandwich osteotomy technique likely contribute to its lower complication rates compared to alternative methods.

The use of short implants has shown promise in reducing the number of surgeries, complications, and patient morbidity, especially in the posterior mandible where bone density and available height are often limited. Short implants utilize the existing bone without requiring additional bone grafting procedures. However, the situation differs in the upper anterior aesthetic zone with a high smile line due to critical aesthetic considerations. In cases where gingival aesthetics are crucial, short implants may not adequately support soft tissue contours, potentially leading to undesirable outcomes such as visible implant edges or gingival recession. Thus, while short implants may be suitable for certain regions of the mouth, they might not be ideal for the upper anterior aesthetic zone, where both functional and aesthetic considerations are paramount. In such cases, alternative treatment options like bone grafting or longer implants may be more appropriate to achieve optimal outcomes and patient satisfaction.

This review focuses exclusively on the anterior maxilla region for treating vertical bone defects and does not provide evidence on the efficacy of the sandwich osteotomy

technique in the lower anterior mandible and upper posterior maxilla. Only a few authors have reported on this procedure in these areas, and their studies feature small sample sizes and limited follow-up periods. (32,33).

Finally, the sandwich osteotomy technique represents a reliable, evidence-based treatment option for addressing vertical bone defects in the anterior maxilla prior to implant placement, with follow-up data at 4 and 6 months. However, additional randomized clinical trials with long-term observation are necessary to further evaluate the efficacy of this technique. These studies should aim to identify the optimal grafting material, assess the vertical stability of the augmented alveolar ridge, and document the long-term (5-10 years) success rate of dental implants. Furthermore, the applicability of the sandwich osteotomy technique for treating vertical atrophic defects in the anterior mandible and posterior maxilla also needs to be investigated and reported.

Conclusion

In summary, segmental sandwich osteotomy represents a promising approach for vertical bone augmentation in the anterior maxilla, offering several potential advantages over traditional techniques. Performing sandwich osteotomy with simultaneous implant placement using patient-specific guides provides efficient and promising results in a single-stage procedure, improving palatal tipping compared to conventional free-hand surgery. However, further research is necessary to fully understand its efficacy, predictability, and long-term outcomes. By addressing these gaps in the literature, this study aims to contribute to the evidence base supporting the use of segmental sandwich osteotomy in implant dentistry, ultimately enhancing patient care and treatment outcomes.

Future Outlook

The research on the clinical outcomes of segmental sandwich osteotomy for gaining vertical bone height in the anterior maxilla before implant placement has opened avenues for further exploration and improvement in implant dentistry. As we look to the future, several areas emerge that warrant attention and investigation:

Refinement of Surgical Techniques:

Continued research efforts should focus on refining the surgical techniques associated with segmental sandwich osteotomy. This includes exploring variations in osteotomy

patterns, grafting materials, and fixation methods to optimize outcomes and minimize complications.

Long-term Follow-up Studies:

Long-term follow-up studies are essential to assess the stability and longevity of the augmented bone and dental implants following segmental sandwich osteotomy. These studies will provide valuable insights into the durability of treatment outcomes and inform clinicians about the need for additional interventions or maintenance.

Comparative Studies:

Comparative studies comparing segmental sandwich osteotomy with other established techniques for vertical bone augmentation in the anterior maxilla are warranted. Such studies will help elucidate the relative efficacy, safety, and cost-effectiveness of different approaches, enabling clinicians to make informed treatment decisions.

Predictive Modelling and Risk Assessment:

Developing predictive models and risk assessment tools can aid clinicians in identifying patients who are most likely to benefit from segmental sandwich osteotomy. By stratifying patients based on their risk profile and treatment needs, clinicians can tailor treatment plans to optimize outcomes and minimize risks.

Integration of Technology:

The integration of advanced imaging modalities, computer-aided design and manufacturing (CAD/CAM), and navigational systems holds promise for enhancing the precision and predictability of segmental sandwich osteotomy procedures. These technologies can assist surgeons in planning and executing procedures with greater accuracy and efficiency.

Patient-reported Outcomes:

Incorporating patient-reported outcomes measures (PROMs) into clinical studies can provide valuable insights into the impact of segmental sandwich osteotomy on patients' quality of life, satisfaction, and functional outcomes. Understanding patients' perspectives and experiences will help improve patient-centered care and treatment outcomes.

Overall, the future outlook for research on segmental sandwich osteotomy in implant dentistry is promising. By addressing the aforementioned areas of focus, clinicians and researchers can further advance our understanding of this technique and continue to improve patient care and treatment outcomes in the field of implant dentistry.

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References

1. Mansour HH, Badr A, Osman AH, Atef M. Anterior maxillary sandwich osteotomy technique with simultaneous implant placement: A novel approach for management of vertical deficiency. Clin Implant Dent Relat Res. 2019 Feb;21(1):160–8.

2. Jensen OT, Kuhlke L, Bedard JF, White D. Alveolar Segmental Sandwich Osteotomy for Anterior Maxillary Vertical Augmentation Prior to Implant Placement. J Oral Maxillofac Surg. 2006 Feb;64(2):290–6.

3. Nazzal SQ, Al‐Dubai M, Mounir R, Ali S, Mounir M. Maxillary vertical alveolar ridge augmentation using computer‐guided sandwich osteotomy technique with simultaneous implant placement versus conventional technique: A pilot study. Clin Implant Dent Relat Res. 2021 Dec;23(6):842–50.

4. Daga D, Mehrotra D, Mohammad S, Singh G, Natu SM. Tentpole technique for bone regeneration in vertically deficient alveolar ridges: A review. J Oral Biol Craniofacial Res. 2015 May;5(2):92–7.

5. Zhao R, Yang R, Cooper PR, Khurshid Z, Shavandi A, Ratnayake J. Bone Grafts and Substitutes in Dentistry: A Review of Current Trends and Developments. Molecules. 2021 May 18;26(10):3007.

6. Ferraz MP. Bone Grafts in Dental Medicine: An Overview of Autografts, Allografts and Synthetic Materials. Materials. 2023 May 31;16(11):4117.

7. Kumar VV, Ebenezer S, Thor A. Bone Augmentation Procedures in Implantology. In: Bonanthaya K, Panneerselvam E, Manuel S, Kumar VV, Rai A, editors. Oral and Maxillofacial Surgery for the Clinician [Internet]. Singapore: Springer Nature Singapore; 2021 [cited 2024 Feb 26]. p. 407–26. Available from: https://link.springer.com/10.1007/978-981-15-1346-6_19

8. Vaquette C, Mitchell J, Ivanovski S. Recent Advances in Vertical Alveolar Bone Augmentation Using Additive Manufacturing Technologies. Front Bioeng Biotechnol. 2022 Feb 7;9:798393.

9. Schettler D, Holtermann W. Clinical and experimental results of a sandwich-technique for mandibular alveolar ridge augmentation. J Maxillofac Surg. 1977 Jan;5:199–202.

10. Bera R, Tandon S, Singh A, Bhattacharjee B, Pandey S, Chirakkattu T. Sandwich osteotomy with interpositional grafts for vertical augmentation of the mandible: A meta-analysis. Natl J Maxillofac Surg. 2022;13(3):347.

11. Buser D, Urban I, Monje A, Kunrath MF, Dahlin C. Guided bone regeneration in implant dentistry: Basic principle, progress over 35 years, and recent research activities. Periodontol 2000. 2023 Oct;93(1):9–25.

12. Ma G, Wu C, Shao M. Simultaneous implant placement with autogenous onlay bone grafts: a systematic review and meta-analysis. Int J Implant Dent. 2021 Dec;7(1):61.

13. Cunha G, Carvalho PHDA, Quirino LC, Torres LHS, Filho VAP, Gabrielli MFR, et al. Titanium Mesh Exposure After Bone Grafting: Treatment Approaches—A Systematic Review. Craniomaxillofacial Trauma Reconstr. 2022 Dec;15(4):397–405.

14. Stucki-McCormick S, Clarizio L. Distraction osteogenesis for dental implants. J Oral Maxillofac Surg. 2003 Aug;61(8):101.

15. Al-Dubai M, Mounir R, Ali S, Mounir M. Maxillary vertical alveolar ridge augmentation using sandwich osteotomy technique with simultaneous versus delayed implant placement: A proof of principle randomized clinical trial. Clin Implant Dent Relat Res. 2023 Feb;25(1):77–86.

16. El Zahwy M, Taha SAAK, Mounir R, Mounir M. Assessment of vertical ridge augmentation and marginal bone loss using autogenous onlay vs inlay grafting techniques with simultaneous implant placement in the anterior maxillary esthetic zone: A randomized clinical trial. Clin Implant Dent Relat Res. 2019 Dec;21(6):1140–7.

17. El Hadidy MS, Mounir M, Abou-Elfetouh A, Barakat A. Assessment of vertical ridge augmentation and labial prominence using buccal versus palatal approaches for maxillary segmental sandwich osteotomy (inlay technique): A randomized clinical trial. Clin Implant Dent Relat Res. 2018 Oct;20(5):722–8.

18. Mounir M, Mounir S, Abou-Elfetouh A, Shaker MA. Assessment of vertical ridge augmentation in anterior aesthetic zone using onlay xenografts with titanium mesh versus the inlay bone grafting technique: A randomized clinical trial. Int J Oral Maxillofac Surg. 2017 Nov;46(11):1458–65.

19. Roccuzzo A, Marchese S, Worsaae N, Jensen SS. The sandwich osteotomy technique to treat vertical alveolar bone defects prior to implant placement: a systematic review. Clin Oral Investig. 2020 Mar;24(3):1073–89.

20. Kamperos G, Zografos I, Tzermpos F, Iatrou I. Segmental sandwich osteotomy of the posterior mandible in pre-implant surgery - A systematic review. Med Oral Patol Oral Cirugia Bucal. 2016;0–0.

21. Starch-Jensen T, Nielsen HB. Sandwich osteotomy of the atrophic posterior mandible with interpositional autogenous bone block graft compared with bone substitute material: a systematic review and meta-analysis. Br J Oral Maxillofac Surg. 2020 Dec;58(10):e237–47.

22. Starch-Jensen T, Nielsen HB. Prosthetic Rehabilitation of the Partially Edentulous Atrophic Posterior Mandible with Short Implants (≤ 8 mm) Compared with the Sandwich Osteotomy and Delayed Placement of Standard Length Implants (> 8 mm): a Systematic Review. J Oral Maxillofac Res [Internet]. 2018 Jun 29 [cited

2024 Feb 26];9(2). Available from: http://www.ejomr.org/JOMR/archives/2018/2/e2/v9n2e2ht.htm

23. Nóia CF, Ortega-Lopes R, Kluppel LE, Sá BCMD. Sandwich Osteotomies to Treat Vertical Defects of the Alveolar Ridge. Implant Dent. 2017 Feb;26(1):101–5.

24. Rachmiel A, Emodi O, Rachmiel D, Israel Y, Shilo D. Sandwich osteotomy for the reconstruction of deficient alveolar bone. Int J Oral Maxillofac Surg. 2018 Oct;47(10):1350–7.

25. Marconcini S, Covani U, Giammarinaro E, Velasco-Ortega E, De Santis D, Alfonsi F, et al. Clinical Success of Dental Implants Placed in Posterior Mandible Augmented With Interpositional Block Graft: 3-Year Results From a Prospective Cohort Clinical Study. J Oral Maxillofac Surg. 2019 Feb;77(2):289–98.

26. Geng Y, Zhou M, Parvini P, Scarlat S, Naujokat H, Abraha SM, et al. Sandwich osteotomy in atrophic mandibles: A retrospective study with a 2- to 144-month follow-up. Clin Oral Implants Res. 2019 Oct;30(10):1027–37.

27. Terheyden H, Meijer GJ, Raghoebar GM. Vertical bone augmentation and regular implants versus short implants in the vertically deficient posterior mandible: a systematic review and meta-analysis of randomized studies. Int J Oral Maxillofac Surg. 2021 Sep;50(9):1249–58.

28. Felice P, Cannizzaro G, Checchi V, Marchetti C, Pellegrino G, Censi P, et al. Vertical bone augmentation versus 7-mm-long implants in posterior atrophic mandibles. Results of a randomised controlled clinical trial of up to 4 months after loading. Eur J Oral Implantol. 2009;2(1):7–20.

29. Bormann KH, Suarez-Cunqueiro MM, Von See C, Kokemüller H, Schumann P, Gellrich NC. Sandwich osteotomy for vertical and transversal augmentation of the posterior mandible. Int J Oral Maxillofac Surg. 2010 Jun;39(6):554–60.

30. Chan C, Mirzaians A, Le BT. Outcomes of alveolar segmental ‘sandwich’ osteotomy with interpositional particulate allograft for severe vertical defects in the anterior maxilla and mandible. Int J Oral Maxillofac Surg. 2021 Dec;50(12):1617–27.

31. Bell RE. Palatal Approach to the Anterior Maxillary Sandwich Osteotomy. J Oral Maxillofac Surg. 2013 Jun;71(6):1005–9.

32. Moon JW, Choi BJ, Lee WH, An KM, Sohn DS. Reconstruction of Atrophic Anterior Mandible Using Piezoelectric Sandwich Osteotomy: A Case Report. Implant Dent. 2009 Jun;18(3):195–202.

33. Tanaka K, Sailer I, Kataoka Y, Nogami S, Takahashi T. Sandwich bone graft for vertical augmentation of the posterior maxillary region: a case report with 9-year follow-up. Int J Implant Dent. 2017 Dec;3(1):20.